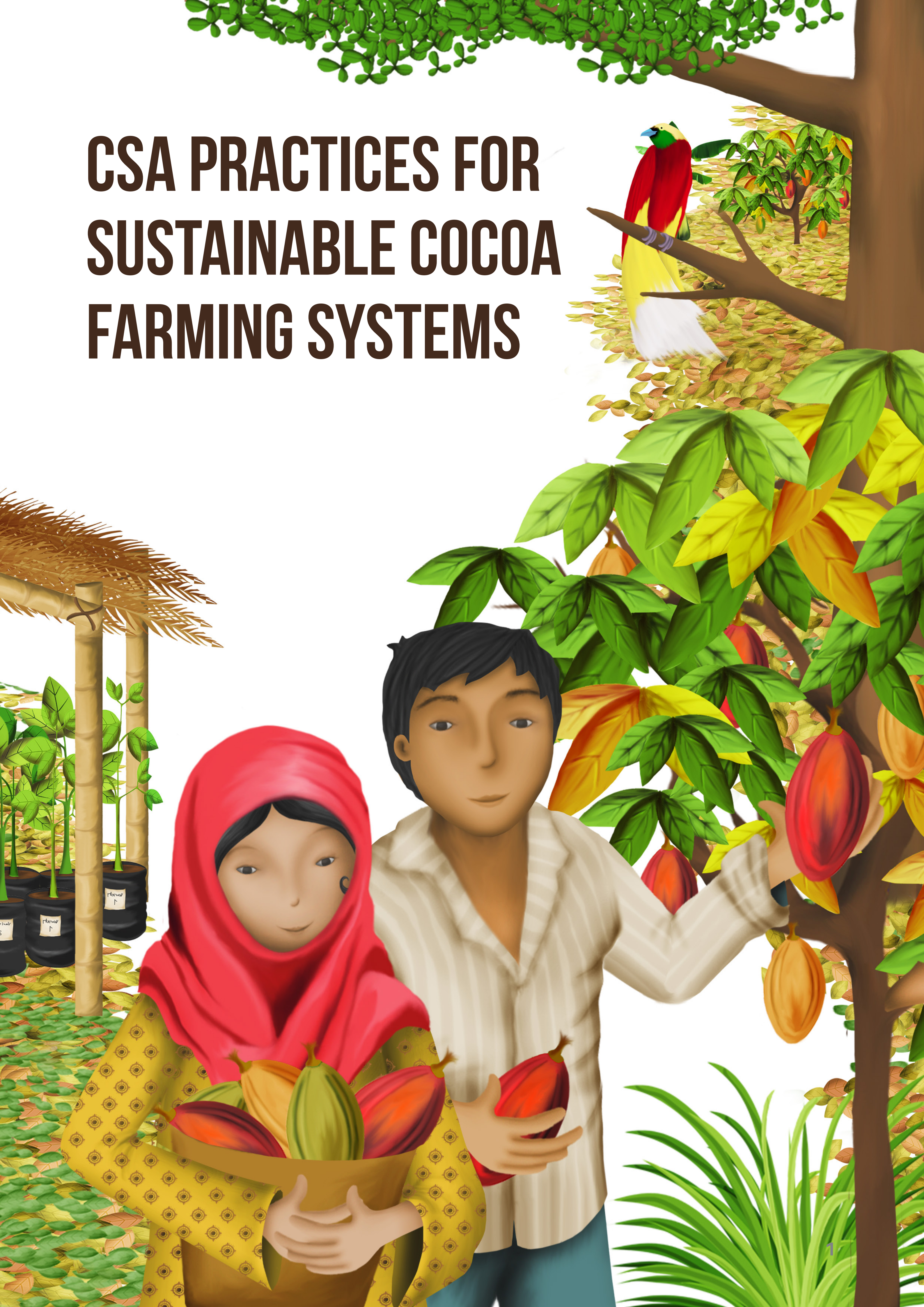
CSA PRACTICES FOR SUSTAINABLE COCOA FARMING SYSTEMS



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CLIMATE CHANGE HAZARDS AND IMPACTS

Cocoa (Theobroma cacao) is extremely vulnerable to climate change. Global temperatures have risen by about 0.85°C in the last century. Climate change scenarios predict further increases of 1.4–3.1°C by 2100, accompanied by changes in seasonality and spatial distribution of rainfall, as well as rising sea levels. These climatic changes are expected to have a significant impact on cocoa origins, and in some regions the effects are already being felt. Less suitable weather can exacerbate the usual challenges of soil fertility, aging trees and pest and disease pressures on existing farms, which increases incentives for cocoa producers to encroach upon forest land in pursuit of more favourable growing conditions for their cocoa trees. Climate change will shape the future production of cocoa and requires mutual cooperation amongst sector stakeholders to tailor responses to its differentiated impacts.

RISING TEMPERATURE

The gradual increase in temperature can trigger several agroecosystem effects including accelerated decomposition of soil organic matter and increased evapotranspiration rate, which reduces soil moisture and negatively affects soil health if precipitation does not increase at the same rate. Additionally the cocoa tree development rate (organ lifespan, fruit ripening) is accelerated. Periods of heat and water stress generate physiological problems in plants such as stomatal closure thus causing wilting of leaves, reduced photosynthesis and pollination rate linked to pollen sterility, causing fruit losses or reduced pod size, and a generalized reduction in productivity and the plant life cycle. Compromised plant health can be exacerbated by pest and disease outbreaks.

CHANGES IN RAINFALL PATTERNS/ DROUGHT

A shift in rainfall patterns may lead to periods of drought or water logging, both conditions which cause water stress and negatively affect plant photosynthesis as well as nutrient uptake, transport, and distribution. This depresses plant growth, overall productivity and bean size. Shifting rainfall patterns can compromise flowering and subsequent pod setting, either due to flower abortion, or reduced effectiveness of pollination. Susceptibility to pests (e.g. pod borer, Helopeltis spp.) and diseases (e.g. black pod, Phytophthora spp.) may also increase. Finally, bean quality could be affected during the fermentation and drying processes.

STRONG WIND

Strong winds increase evapotranspiration rates and can inflict mechanical damage leading to premature leaf fall, plant drying, and defoliation. Damage and fall of branches can also result, and in the worst cases trees are uprooted when the root system is not robust. Full-sun or monocropping systems are susceptible to wind erosion and gradual land degradation.

IMPACTS

Drought
Flooding
Erosion
Low water availability
Crop damage
Crop failure
Pest/disease outbreaks
Phenological changes

CSA TO TACKLE CLIMATE CHANGE IMPACTS

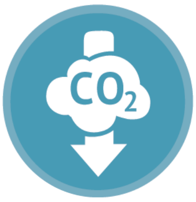
Climate-smart agriculture (CSA) is an integrative approach for transforming conventional landscapes, to support sustainable agricultural production and food security under a changing climate. To attain this goal, CSA aims to deliver triple-wins by contributing to three interrelated objectives: sustainably increasing agricultural productivity and farmers' income (food security), enhancing resilience capacity of farms and farmers to overcome climate change impacts (adaptation), and reducing and/or removing greenhouse gas emissions (GHG) (mitigation).

FOOD SECURITY

CSA achieves food and nutrition security for smallholder cocoa families through encouraging the planting of annual and perennial crops in agroforestry systems both for sale or on-farm consumption; raising incomes through sustainable increases in cocoa productivity and sale of alternative products from intercropped species. Food security goals must include marginalized poor who are more vulnerable to climate change effects.

ADAPTATION

In contrast to full-sun systems, adaptation in cocoa farms refers to restoration and maintenance of ecosystem functions and services provided by forests/trees and biodiversity (e.g. pollination, pest and disease regulation, soil health, etc.). By building socio-ecological resilience against climate hazards, low cocoa market prices and infrastructure development, whilst promoting productivity targets under consistent shade levels, diversified shaded systems allow on-farm generation of agricultural inputs for crop management and alternative livelihood opportunities. Adaptation goals must include gender aspects, particularly fostering decision-making power, technical knowledge, and access to resources of women, who typically have less access and legal right to the land or other resources that provide capacity to cope with climate change.



MITIGATION

CSA reduces greenhouse gas emissions and promotes carbon dioxide storage through diverse decisions and activities from the plot-level to the landscape-level. Preventing and reversing deforestation in natural/virgin and agricultural areas respectively, enhancing soil health, transitioning to organic and local inputs, and use of more woody species constitute key strategies to minimize carbon footprints and environmental costs of cocoa production.

Identifying and prioritizing CSA responses requires integration of multiple objectives and managing trade-offs between food security, adaptation and mitigation. In order to ensure climate-smartness, a system cannot be optimized for only one of these aspects of without considering the effect on the others. Thus CSA practices applied in heterogeneous/diversified cocoa agroecosystem should be assessed for synergies and minimization of trade-offs through consideration of costs, benefits and stakeholder aims.

CSA ACROSS MULTIPLE SCALES AND ACTORS

CSA responses constitute a range of actions that can be undertaken at the different scales of the enabling environment, landscape, farm or plot. These actions span from policies, finance, insurance and value chain interventions to technologies such as digital ICTs, farm management practices and planting material. No matter at what scale, CSA must always maintain ecosystem services because of the important benefits to agriculture of climate regulation, water, soil and biodiversity provisioning. CSA is also forward-looking and therefore takes into account the relevance of responses under future climatic conditions and the sustainability of the benefits over time. These factors all contribute to creation of either an enabling or disabling environment for adoption of CSA practices and are therefore important to identify priority CSA responses for a particular context. In the case of this document, described CSA responses are at the farm and plot level, as this is the scale at which cocoa producers have the most direct control. However, careful consideration of the local contexts at landscape and enabling environment (socio-cultural, economic, environmental, institutional, and political) scales are important to ensure that producers enabled to choose appropriate CSA responses.

Enabling environment

- Infrastructure and physical capital
- Inclusive markets and value chains
- Gender and social inclusion
- Information and knowledge sharing
- Climate information services
- Insurance and financial services
- Agricultural and environmental policy framework

Landscape-level

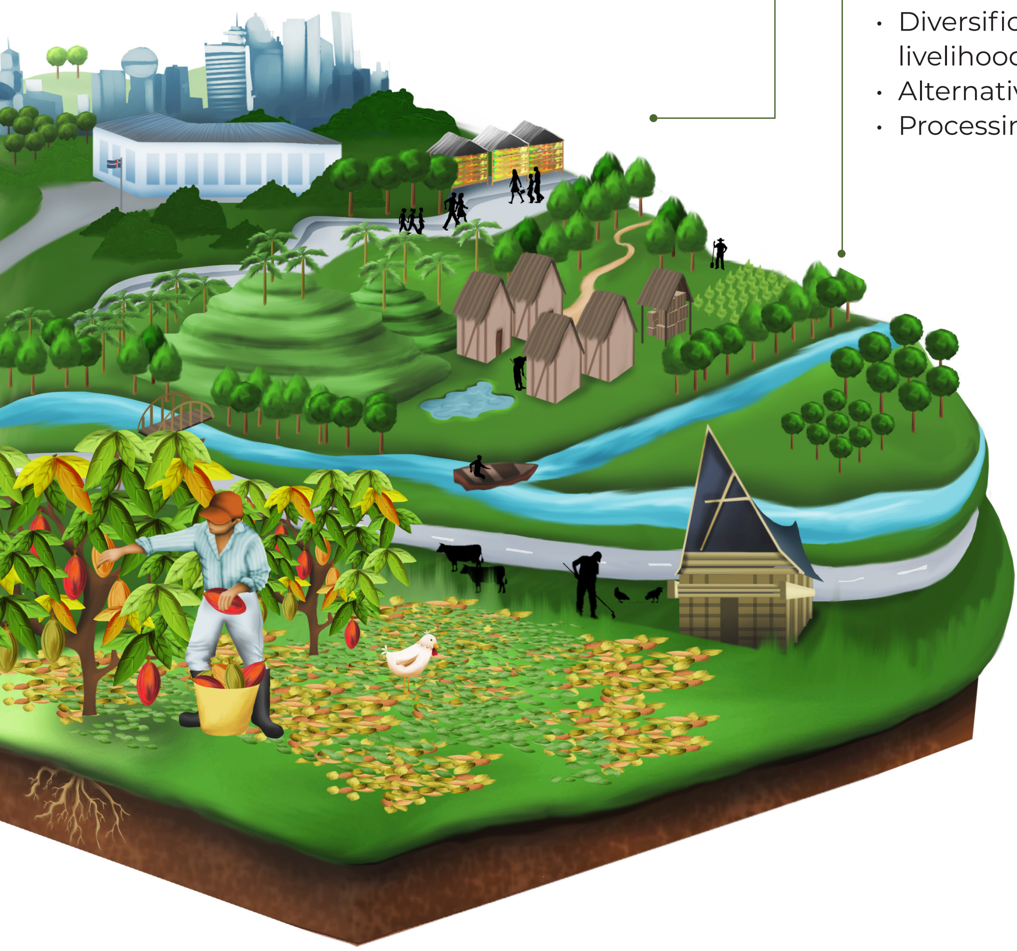
- Land use planning
- Biodiversity and ecosystems conservation and restoration
- Ecosystems services provision and regulation
- Cooperation networks

Farm-level

- Pest and disease regulation
- Alternative cropping system
- Diversification of farm products and livelihoods
- Alternative energy sources
- Processing and value addition

Plot-level

- Diversity of seeds and improved planting material
- Eco-efficient inputs use
- Soil and water management



ENABLING CSA ADOPTION

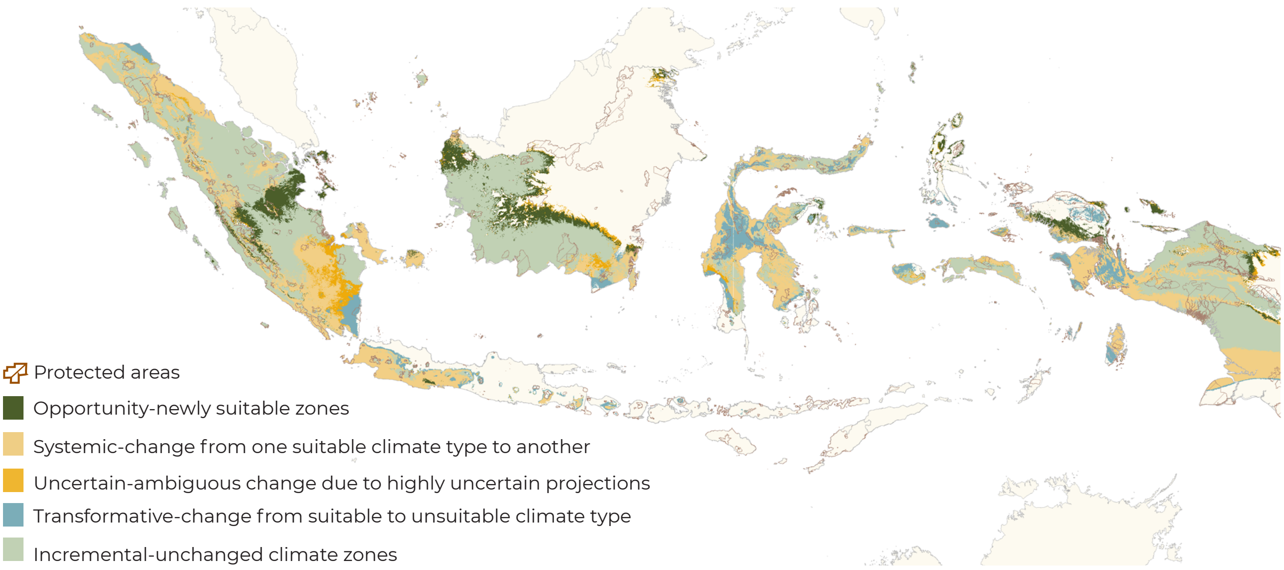
Climate change is not uniform, but varies over space and time and impacts households differently. CSA responses should reflect this variability with site-specific recommendations. Recommendations that account for local variations are more suited to the needs and capacities of local stakeholders, and therefore have higher adoption potential. For project implementers, the result of accounting for these dimensions of CSA is higher up-take, improved resilience and larger social impact returns on investments.

Local variation in timing: CSA should be implemented through a stepwise approach, whereby the benefits of each improvement step free resources for the next step. For example, this could mean that rejuvenation and pruning of non-productive trees are required in a first step, while weeding, mulching and pest and disease management only make a difference in a second step. Fertilizer, manure or compost application become relevant only after the preceding steps have been implemented. For practices requiring large financial or labor investment, implementation may be gradual with selected cacao trees in order to avoid a large drop in income.

Local variation in typology of producer households: Responses to barriers to CSA adoption require ways to deal with producer heterogeneity. Next to ecological heterogeneity in aspects such as climate and soil fertility, CSA promotion should take into account the socio-economic heterogeneity of the target beneficiaries. Characterization of producers into different types of households enables tailoring of responses to their different needs. Both the ecological and socio-economic information are relevant for identifying similar producers in terms of household characteristics and challenges, but which show differences in adoption of cacao management strategies and productivity. This information can be used to match nearby farmers of similar typology but different adoption and cacao yield characteristics to exchange experiences and thereby stimulate adoption of CSA within the community.

Local variation in climate: Impact of future climates on growing regions is needed to select locally appropriate CSA. In this example, Indonesia is vulnerable to climate change. Climate change projected scenarios reveal increases in temperature between 0.7 to 2.3 °C in the next couple of decades, as well as increasing variability in the rainfall patterns, especially timing and seasonality. These hazards, coupled with a more frequent and intense El Niño-Southern Oscillation cycle (ENSO) might intensify the variated effects of drought and intense rains of different cocoa agroecosystems, increasing the need for climate-specific adaptation strategies.

ADAPTATION NEEDS



CSA PRACTICES FOR SUSTAINABLE COCOA FARMING SYSTEMS

DEVELOPMENT/CHOICE OF IMPROVED/TOLERANT COCOA VARIETIES

WHY?

The success of a climate-smart cocoa farm depends to a large extent on the characteristics of the cocoa varieties adopted by the farmers. The development and right choice of locally improved varieties is an essential CSA practice to reduce the crop's vulnerability to biotic and abiotic stresses. Genetic diversification through the use of various planting material (varieties/clones) with special traits, such as higher resistance to pests and diseases, tolerance to climatic hazards (drought and heat) and good bean quality, increase resilience to climate change impacts

- Reduces yield losses and harvest failure.
- Promotes production stability and regularity.
- Potential increases in profits due to greater crop yield and produce quality.
- Reduces the need for external inputs (e.g. pesticides) hence reducing production costs.

- Drought/heat-tolerant varieties enhance water use efficiency per unit of produce.
- Pest/disease-resistant varieties reduce the use of synthetic pesticides, hence reducing environmental pollution.
- Minimizes negative impacts on human health, biodiversity and ecosystem services such as pollination.

- Reduces dependency on synthetic pesticides, thus reducing the carbon footprint associated with the production, packaging, transport, and disposal of these inputs along the value chain.
- In some contexts reduces energy consumption for water and pesticides management.

HOW?

- Developing/choosing high-yielding varieties suitable to specific agro-ecological zones and accounting for future climates.
- Developing/choosing drought- and heat-tolerant, or pest- and disease-resistant varieties depending on local context.
- If there is no access to improved varieties or clones, use seeds or grafts from healthy and productive trees.
- Promoting incentive/subsidy mechanisms needed to enable farmers to afford seedlings cost.
- Establishing and maintaining on-farm or community based nurseries for reliable supply of high quality seedlings.
- Fostering varieties development and distribution by research organizations, input suppliers or farmer's organization.
- Reinforcing local, national, and regional collaboration in cocoa breeding programs.

INTERCROPPING, GROWING SHADE AND WINDBREAK TREES

WHY?

Full-sun cocoa farming systems can be extremely vulnerable to climate shocks and are more dependent on external/off-farm inputs. Agricultural diversification through intercropping and introduction of native trees for shade and as windbreaks plays a vital role in ensuring household food and nutritional security, and increasing rural employment, since it enables a diversified food-and-cash crop livelihood strategy. It can also positively impact environmental indicators such as biodiversity, and directly contributes to climate change mitigation.

- Appropriately selected species and densities can favor cocoa tree growth, development, and maximum expression of yield and quality potential.
- Allows the diversification of farm agricultural activities and products for sale and self-consumption.
- Diversifies income which increases farmer's resilience and therefore their ability to respond in time to address crop failure risks.
- Smooths farmer income through a more stable and constant production.

- Creates a micro-climate that provides a buffer against high temperatures, drought, and wind speed, by stabilizing temperature and maintaining soil moisture.
- Minimizes soil erosion and runoff.
- Improves habitat connectivity for wildlife, supports higher levels of biodiversity such as pollinators and biological control agents.
- Improves nutrient cycling efficiency by extracting and releasing subsoil nutrient through litter addition and decomposition.
- Promotes biological nitrogen fixing, soil health and fertility.

- Intercropping with leguminous species allows the reduction of off-farm input needs such as nitrogen-based fertilizers.
- Decreases synthetic pesticides and fertilizers use, and carbon footprint associated with their production, packaging, transport, and disposal along the value chain.
- Increases soil organic matter (SOM) and soil organic carbon (SOC) content.
- Captures and stores carbon in woody biomass in trunks, branches and roots.

HOW?

- Protecting seedlings of native species that grow naturally on the farm, and maintaining seedlings in the nursery for transplanting.
- Intercropping with annual crops such as cassava, chili pepper, plantain, etc.
- Planting temporary shade trees such as banana and fast growing leguminous trees such as Gliricidia spp. or Erythrina ssp.
- Planting permanent native shade trees such as edible fruit trees (durian, soursop), leguminous and timber trees (mahogany) that also serve as windbreak trees when planted on perimeter of plots or against main strong wind direction to protect cocoa trees from damage (branch breaking, leaves and pod dropping, trees uprooting).
- Adequate spacing and pruning of shade trees to ensure effective shade provision without compromising cocoa tree growth and yield. Shade density in cocoa of 0–3 years should reach 70%, and be reduced to 30% from year 4 onwards.

MULCHING

WHY?

Mulching methods in cocoa farms are directly connected to soil and plant health, and therefore productivity. Constant soil cover allows replenishment and preservation of high soil organic matter and soil moisture. This promotes above- and below-ground habitat conditions that enable macro- and micro-biota to develop various processes that enhance biological, chemical and physical characteristics of the soil (e.g. activity of microorganisms, pH, mineral fertility, porosity, infiltration), which in turn creates the enabling conditions for the development of strong and healthy crops.

- Overall agro-ecosystem productivity is maintained, thus increasing yield or buffering against losses.
- Balanced soil characteristics help to prevent against diseases and enhance crop quality and longevity.
- Reduces incidence/rate of weed and soil-borne diseases, hence decreasing purchase of fungicides and herbicides.
- Increases water- and nutrient-use efficiency per unit of output.

- Reduces soil exposure to direct sunlight and rain, hence preventing erosion, nutrient loss and drying (retains soil moisture).
- Fosters and conserves soil biodiversity, hence facilitating decomposition of organic matter and improving soil nutrient retention and overall fertility.
- Prevents soil compaction.

- Allows the reduction of off-farm input needs such as synthetic pesticides and fertilizers.
- Decreases synthetic fungicide and fertilizer use, and carbon footprint associated with their production, packaging, transport, and disposal along the value chain.
- Increases soil organic matter (SOM) over the cropping cycle, having a significant CO_2 sink capacity.

HOW?

- Keeping disease-free residues from weeding and cocoa leaves on the ground.
- Using leaf/tree litter from intercropped temporary and permanent crops and shade trees such as pruned branches, banana/plantain pseudo stems and leaves.
- In full sun cocoa farms where organic material for mulching is limited, put on ground a layer of leaves around base of cocoa trees.
- Planting of living mulch/cover crops (in some cases at early stage of cocoa establishment or in open spaces) that farmers can also consume or sell such as beans, cowpea, groundnuts, and other legumes or vegetables.

INTEGRATED PEST AND DISEASE MANAGEMENT (IPM)

WHY?

Implementing various pest and disease management strategies contributes to minimizing negative socio-economic and environmental impacts caused by conventional control practices (reliance on use of synthetic pesticides). Continued use of synthetic pesticides offers a temporary solution, but is ineffective over the long term and might lead to negative side effects including pest resistance (a serious threat), biodiversity reduction, environmental pollution, and risk to human health.

- Minimizes yield losses and pest damage or harvest failure.
- Promotes sustainable yield increase.
- Increases cost-effectiveness in the long term by reducing the need for external inputs (e.g. pesticides) hence reducing production costs (purchase, application, and disposal).
- Potential benefits to produce quality and market recognition.

- Increases crop/farm resilience to pest and diseases outbreaks.
- Reduces the potential for air and ground water pollution.
- Decreases exposure of producers and consumers to pesticides (contact, inhalation, or ingestion) and related negative effects on health.
- Protects biodiversity and ecosystem services such as pollination, natural predators, beneficial organisms that prevent infection.

- Reduces synthetic pesticide use thus avoiding the carbon emissions associated with the production, packaging, transport, and disposal of these inputs along the value chain.
- In some contexts reduces energy consumption for water and pesticides management.
- Reduces negative side effects on soil microorganism and important functions such as nitrogen cycling.

HOW?

- The most effective way is through **prevention:**
  - Developing/choosing pest/disease tolerant varieties suitable to local agro-ecological zones.
  - Understand the factors and environmental conditions that promote growth and spread of pest and diseases.
  - Maintaining soil fertility (mulching, composting etc.), as the ability of crops to resist/tolerate insect pests and diseases is strongly linked to good soil health and vigorous soil biological activity.
  - Timely pruning to allow sunlight to reach the lower part of the tree canopy, preventing development of diseases.
- **Monitoring** to adequately identify when actions are needed:
  - Regular field visits to monitor and for timely detection of pests and diseases.
  - Set action thresholds to inform when, where and what actions are required.
- **Intervening** with various management strategies:
  - Cultural and physical practices: e.g. trapping; timely pruning, collection, and disposal of infected branches, pods, and litter (sanitation, bury).
  - Ecological methods: Repellent and trap crops ("push-pull effect"); natural enemies; pheromones; natural organic compounds from native/nearby plants (e.g. mahogany leaves, lemon grass, etc.).
- Increasing involvement of public and private organizations that provide research, education, and training to farmers and practitioners on IPM methods.

PRUNING

WHY?

Pruning is a key CSA practice to ensure optimal conditions for healthy cocoa production. Both cocoa trees and other intercropped species for shade, food or wind protection can be pruned according to their age or stage of development. Pruning helps regulate the height of the trees, aiding balanced vegetative and productive growth by shaping strong and well-proportioned branches in terms of size, form, and quantity. This helps to create the right micro-light regime and aeration, avoiding excessively shaded or humid conditions that could lead to pests and/or disease outbreaks.

- Allows tree regeneration, hence maintaining crop health and productivity.
- Reduces incidence/rate of pests and diseases, hence decreasing need for purchase of fungicides and herbicides.
- Minimizes the obstruction to access and harvest pods.
- Desuckering reduces excessive growth of young sprouts, optimizing trees' nutrients /energy allocation towards pods.
- Provides byproducts such as wood.

- Reduces the risk of pest/diseases due to well aerated canopy.
- Provides raw material / organic matter for composting and mulching, thus increasing soil fertility.
- Reduces the risk of crop damage from broken and falling branches.
- Increases water- and nutrient-use efficiency per unit of output.

- Indirectly contributes to reducing synthetic pesticides and fertilizers use, hence the carbon footprint associated with their production, packaging, transport, and disposal along the value chain.
- Increases soil organic matter (SOM) over the time, providing a significant CO_2 sink capacity from woody biomass.

HOW?

There are different types of pruning:

- Structural: Can be performed on 1–2 year old trees to ensure symmetrical and stable growth of cocoa trees. It involves selective removal of branches to allow a single and not very tall trunk, low jorquettes and branches well-distributed vertically and horizontally.
- Maintenance: Removal of suckers as well as unproductive and overlapping branches that consume the trees' energy. Conducted 1–2 times per year in the dry season, maintenance pruning allows sunlight to filter to the ground and stay at the canopy level by about 45% and 30%, respectively.
- Sanitation: Weekly removal of branches and pods affected by pest and diseases is necessary to effectively arrest spread of pests and contagious diseases in time. Unlike other types of pruning, sanitation is necessary for affected trees only.
- Pruning with proper and specific tools such as pruning shears or saws to achieve a "clean" wound surface prevents cracks, hence avoiding entry points for pest and disease infection. The cut surface can be covered with slaked lime to further prevent infection.
- Disinfecting pruning tools after each tree or after cutting infected plant parts avoids dissemination of disease.

COMPOSTING

WHY?

Diverse and well-managed compost makes an effective habitat and nutritious fodder for bacteria, fungi, bugs and worms, among other organisms, that enable decomposition and replenishment of soil nutrients extracted by crops. This provides a mild, slow and constant release of macro and micronutrients which are more readily taken up by root systems and ultimately improve plant growth. As a result, better yields are achieved in a sustainable way by reforming the bio-chemical and physical conditions of the soil, with minimal environmental impact, and particularly optimizing the use of farm wastes, reflected as economic and mitigations benefits.

- Promotes sustainable increase in productivity and potential benefits to income due to higher product quality with minimal environmental impact.
- Balanced soil characteristics help to prevent diseases and enhance crop quality and longevity.
- Reduces the need for external inputs (e.g. synthetic fertilizers) hence reducing production costs.

- Fosters and conserves soil microbial activity, hence facilitating decomposition of organic matter, improving farm's hygiene and soil's water and nutrient retention capacity.
- Builds soil fertility by improving bio-chemical and physical soil characteristics over time.
- Promotes efficient use of local/on-farm organic waste including cocoa pod husk and livestock manure.

- Well-managed compost reduces GHG emissions from N_2O produced by microbial nitrification and de-nitrification, and after volatilization and leaching of synthetic fertilizers.
- Allows progressive reduction of off-farm synthetic inputs and related carbon footprint.
- Maintains or improves soil organic matter (SOM) over the time, hence soil carbon stock.

HOW?

- Processing byproduct of cocoa pod husks, crop residues of intercropped species (e.g. lemongrass, banana, and other fruits), and livestock manures.
- Preparing home-made effective microorganism (EM) products made from molasses, alcohol yeast, and rice bran.
- Collecting pod husk and other organic material into a bin or in heaps. Mix with manure, adding water if the manure is excessively dry, then adding prepared EM mixture and covering with banana leaves, a plastic sheet or mud.
- An aerobic composting process requires opening the cover and turning the mixture from time to time. This allows a homogeneous decomposition, encourages growth of thermophilic bacteria that are quick decomposers and avoids very high temperatures that could affect beneficial microorganisms.
- Though a more complicated method, using red worms would facilitate the composting process making it relatively faster and of better quality.

BALANCED AND SOUND APPLICATION OF FERTILIZER

WHY?

Healthy soils and crops are the result of a holistic agroecosystem approach. Sustainable enhancement of soil fertility involves a vibrant macro and micro flora and fauna activity that builds biological, chemical, and physical soil characteristics. In farms where inorganic fertilizers are used, their indiscriminate application can destabilize this soil dynamic and offset immediate benefits with longer term degradation of soil health. Transitioning towards sustainable fertility management entails, first, selecting the right source of nutrients and when inorganic fertilizers are used, ensure that type, quantity, application method, and timing are appropriately informed. Consider factors such as the appropriate growth stage—crop phenology—soil moisture, and weather conditions, aiming to reduce the risk of nutrients leaching, water pollution, and GHG emissions from nitrogen volatilization.

- Increases in productivity per unit of area with minimal environmental impact.
- Balanced soil ecosystem helps to prevent diseases and enhances crop longevity and product quality.
- Leveraging biological nitrogen fixation reduces the need for external inputs (e.g. synthetic fertilizers) hence reducing production costs.
- Avoids crop failure due to the buffering effect against drought.

- Fosters and conserves soil biological activity, hence favoring structure/aeration, water and nutrient holding capacity, and efficient use of nutrients.
- Minimizes soil erosion and runoff.
- Reduces the risk of over fertilization, nutrient imbalances, and toxic effects on plants caused by synthetic fertilizers.
- Reduces risk of leaching and subsequent pollution of water bodies and damage to wildlife.

- Allows progressive reduction of off-farm synthetic inputs and the carbon footprint caused by their production, packaging, transport, application, and disposal.
- Well composted material reduces GHG emissions per unit of produce.
- Maintains or improves soil organic matter (SOM) over the time, hence increasing soil carbon stock.

HOW?

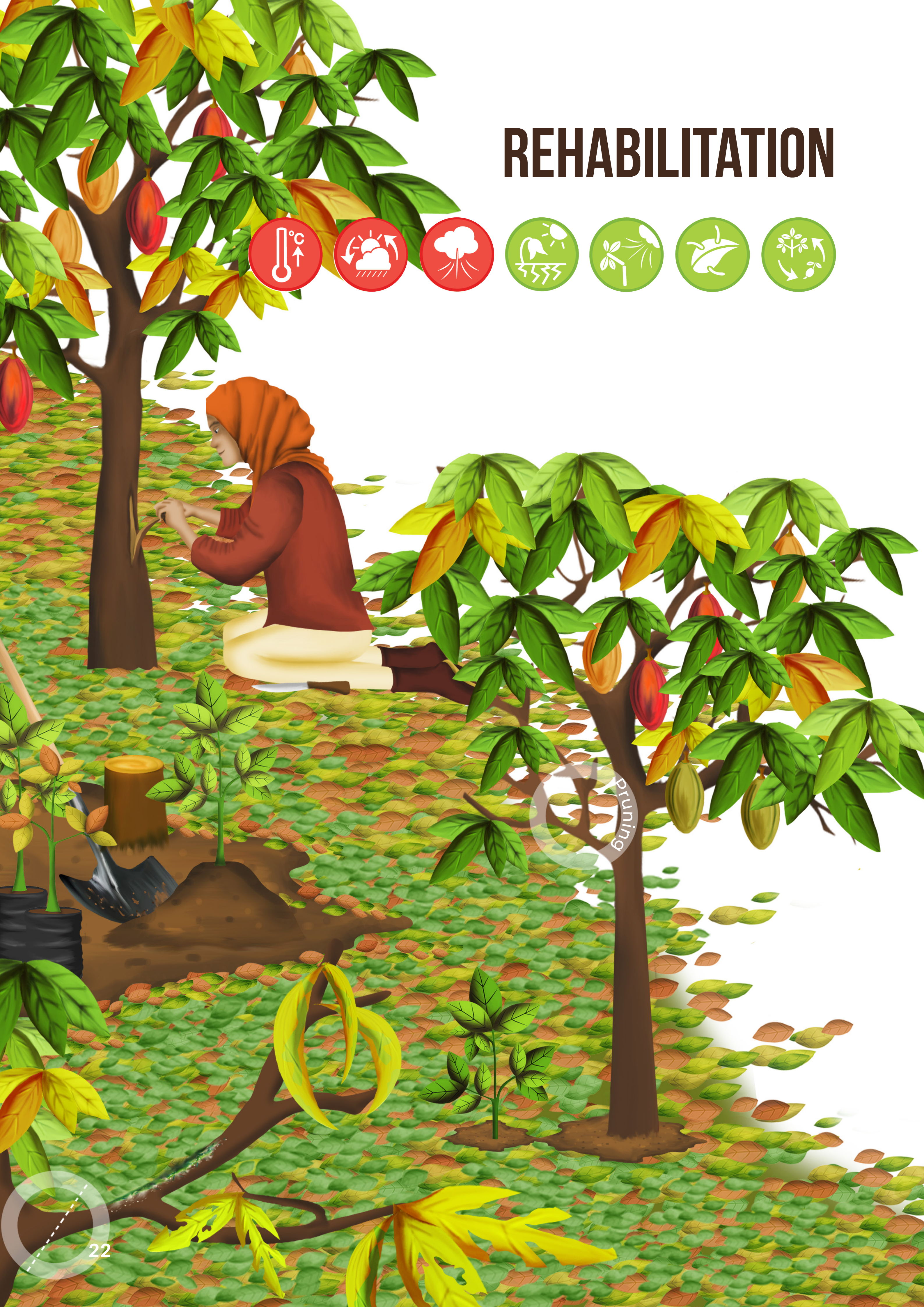
- Carrying out soil fertility tests—there are several laboratory and on-field methods—to determine soil health status, hence planning CSA practices required to attain cocoa tree's nutrient requirements.

- Exploring organic fertilizer sources adapted to farmer's needs, composting made from household biodegradable waste, plant/crop residues and livestock manure is the most common. However, many other alternatives sources and techniques, homemade or purchased, include Effective Microorganisms (EM), vermicomposting, bio- fertilizers, liquid humus, compost tea, ashes, slurries, manures and green manures, to name a few.

- Preparing an informed fertilization plan according to the source, considering the right time of application (crop development phase and weather conditions), the application method (around the plant and covered or in holes outside the dripline), and the correct amount depending on the variables above mentioned.

- Community-based support to construct composting centers are potential alternatives for local cooperation, job creation, and diversification and quality control of organic and biological fertilizers.

REHABILITATION



WHY?

Rising temperature, prolonged periods of drought and extreme heat, uncertain and intensive periods of rainfall, and strong winds are some climatic hazards that progressively reduce the vigor and productive potential of cocoa trees. In parallel, pest and diseases outbreaks exacerbated by the seasonal changes in temperature and precipitation, and weak crop management practices in full-sun farms, are factors that further negatively affect the production system. Particularly in relation to its productive lifetime, cocoa's reduced growth capacity and vulnerability to pests and diseases is accelerated by the less favorable conditions.

- Planting new trees and/or rejuvenating old trees helps to maintain or improve yield.
- Grafting makes it possible to select rootstocks and scions with desirable traits, allowing for accelerated production and improved plant and bean quality.
- Balanced planting densities ensure optimum production and use of time and space for cocoa trees and/or any intercropped species.

- Allows gradual adoption of varieties that are better adapted to local climatic and soil conditions and incorporate pest/disease resistance, hence minimizing the risk of crop failure, and indirectly reducing the use of synthetic pesticides and associated environmental pollution.
- Provides raw material / organic matter for composting and mulching. Increases water- and nutrient-use efficiency per unit of output.

- Contributes to reducing the amount of external inputs, hence decreasing related carbon footprint caused by their production, packaging, transport, application, and disposal.
- Increased yield reduces the GHG emissions per unit of produce.

HOW?

- Rejuvenating cocoa using side grafting techniques with improved scions is recommended for healthy trees with vigorous base but declining productivity.

- Establishing and maintaining on-farm or community based nurseries for high quality and disease-free seedling production.

- Complete replanting could be expensive, but necessary under high incidence of pest and diseases, or for unproductive trees older than 30 years. However, an alternative strategy for optimizing time and space is selective planting of young cocoaplants/clones under mature trees—that will be gradually pruned and stumped once seedling are well established.

- Grafting should ideally be conducted early in the rainy season. Rootstocks and scions must be free of disease signals or symptoms, equipment must be clean and disinfected, and whether grafting on coppiced trees or seedlings, the scions have to be covered with waterproof tape or wax sealant to prevent dehydration or excessive humidity causing disease.

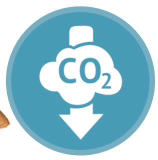
MORE THOROUGH DRYING OR FERMENTATION OF COCOA BEANS

WHY?

The intensity or prolongation of the rainy season can increase the water content/humidity of cocoa beans, which extends the drying time. Worse, excess humidity can slow down or prevent the natural fermentation process, fostering mold contamination and production of mycotoxines (e.g. aflatoxins). On the other hand, drought can alter flavor quality making it more acidic, and a prolonged dry season can increase sugar content in beans making them less suitable for fermentation. In areas where fermentation is done, this may compromise final formation of typical taste and aroma intensity. These factors ultimately reduce flavor quality, having negative implications during marketing due to the low price or rejection of the produce.

- Appropriate drying and fermentation processes ensure greater produce quality, hence fetching higher market prices and improving household income.
- Additional revenue contributes to household food security and allows diversification of income sources thus increasing resilience.

- Preserves cocoa beans sensory characteristics and quality.
- Reduces risk of damage from insects, molds, and other microorganisms, increasing product shelf-life.
- Allows farmers to process and add value to their produce, hence increasing their profit margin.
- Methods such as solar dryers can also be used for food and seed preservation, helping to offset crop losses and phenological changes.



- Increased yields reduce the GHG emissions intensity, meaning less carbon per unit product.
- Use of solar dryers reduces energy consumption compared to electric, firewood or gas powered dryers.

HOW?

- Using local/on-farm materials such as bamboo mats or wooden tables to make the fermentation boxes as well as simple solar dryers—adding clear plastics in the last case— are cost-effective alternatives and prevent damage or reduction of flavor attributes of cocoa beans.
- Controlling the drying or fermentation time and methods, which should ideally range between 5 to 7 days depending on the local humidity and temperature, amount of cocoa beans, method used (linear boxes, stacked boxes, trays, baskets), and even the cocoa variety cultivated. In the case of fermentation, regular mixing/turning after the initial 48 hours allows aeration, homogeneous fermentation and bean quality preservation.
- Selecting the most suitable and efficient drying method or structure design depends on environmental factors such as space, capacity, position/orientation, wind speed and exposure to sunlight. Passive air-flow systems are preferred.
- After drying or fermentation, safe and dry storage until point of sale is important to preserve product value.

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